Broadcast Signal Lab

Memorandum

To Acton Planning Board 2 April 2010

From David Maxson

Re Response of Tower Engineering Professionals, 18 March 2010

Today, we received a response from Tower Engineering Professionals ("TEP") to our critique of the photosimulations they prepared for SBA at the 5-7 Craig Road site. We address the respondent's comments in sequence:

Pg. 3 Para. 3 **Was the balloon height actually measured?**

Respondent says yes, then contradicts by explaining that they relied strictly on the length of the tether (plus balloon's dimensions) to establish the height of the balloon. By "measuring" the balloon height, we mean actually taking a measurement to verify that the errors introduced by catenary (the curve or sag in the tether) and by deflection off vertical from the launch point caused by windage. Further, the respondent says that photographs were taken at the "apex" of flight while observed by the photographer.

In a steady wind, with mild gusts, the apex of a balloon (or blimp) on a tether may not be near the ideal vertical from the launch point. Further, digital cameras tend to take discernable fractions of a second to acquire an image, in which time the balloon may not be on the "apex". For the sake of the following discussion on correcting for windage, let us assume that catenary and apex-capture are not the causes of significant error in the photosimulations. This still leaves basic windage as a potential source of error.

How was the scope (length) of the line adjusted for windage?

Respondent indicates "the Blimp's flight ranged from ~90° to 85°…" [above horizontal]. This seems to be an estimate by eye, because the respondent made no indication of having taken a measurement of the angle of deflection off the vertical. This can be accomplished with a simple tool called an inclinometer. Similarly, the respondent could have triangulated the offset by measuring the horizontal distance from the anchor point to a point directly below the blimp. From such a measurement, a tilt angle could have been calculated. This apparently was not done. Finally, when we attend balloon tests, we carry a simple laser rangefinder and directly measure the balloon height. We have seen work by a civil engineer in this region who takes into account the balloon offset by maintaining communication between the balloon tender and the field photographer; they take an actual offset reading each time a photo is taken, plus the coordinates of the photo site are recorded. Then the resulting image and data are imported into a Computer Aided Design program to ensure that the dimensions of the resulting simulation (height and width) are as accurate as possible.

The respondent also suggests that because the blimp is streamlined, unlike a spherical balloon, this "allows for the blimp to turn into the wind versus being blown off course during the time of high winds during the balloon test." All this observation means is that the blimp, by turning into the wind presents its lowest cross section to the wind. At such an attitude, the blimp still offers substantial wind resistance. The distinction between the blimp whose frontal cross section is 5.2 feet and a balloon of similar diameter is that the blimp has a greater dimension axial to the wind than the balloon. In short, the 5.2 foot diameter blimp has a higher volume-to-windload ratio and therefore more buoyancy than the balloon. This provides an advantage with respect to the lift of the balloon against the tether and indirectly against the wind offset, but it does not eliminate the impact of windage.

Pg. 3 Para. 5 **Nevertheless, a simulated tower set to the balloon height may not be the correct width on the selected photograph.**

The respondent suggests "the length and width of the balloon are known and were clearly stated in the letter report..." This statement is correct; however the next step remains unexplained. The apparent size of the balloon in the photographs is said to have been used to estimate the width of the tower during creation of the photosimulations. It is difficult to estimate the width of a tower based on the width of a balloon at a substantial distance as captured on a digital picture; the fine details of such a small image may be represented by only a small number of pixels (dots) in the image. Further, digital photos may employ data reduction techniques that can add error to the dimensions of fine details.

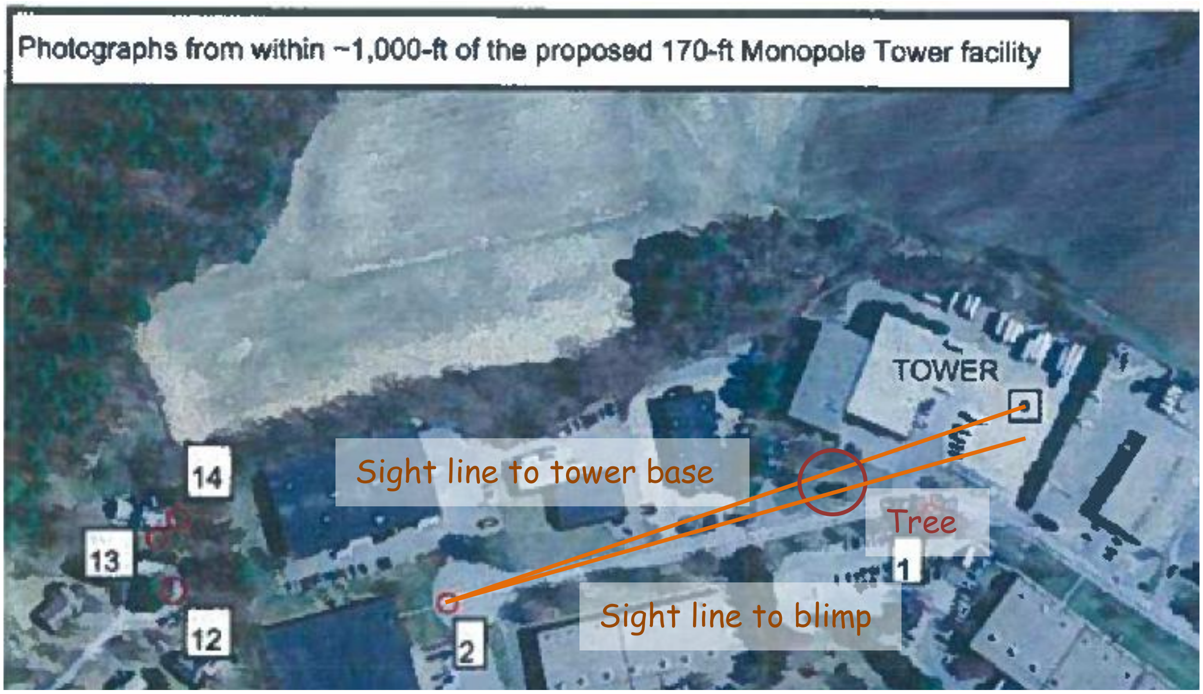

Figure 1 – TEP Aerial Photo Mapping <1000 ft Photo Locations

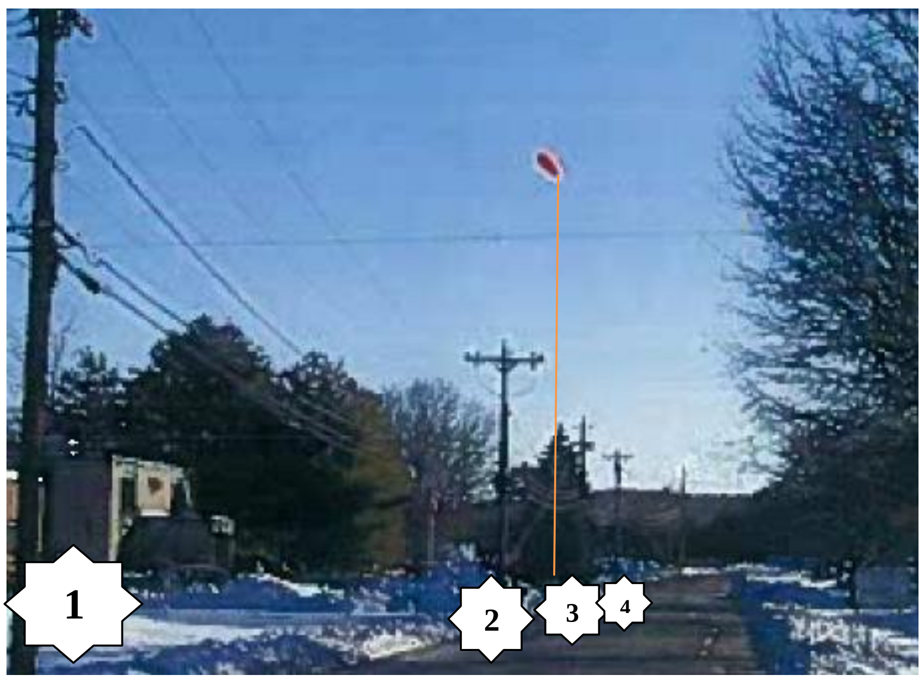

Figure 2 - TEP Balloon Photo from Location 2 on <1000 ft Map (Figure 1)

In addition the balloon is, at its narrowest, 5.2 feet and, at its widest, 13 feet – a 2.5 to 1 ratio – resulting in an uncertainty of the apparent width of the blimp at any particular angle from which the photographs were taken. Figure shows the effect of the blimp at less than a broadside angle in a photo taken from less than 1000 feet.[1]

Figure 1 and Figure 2 together demonstrate the windage error of the blimp. In Figure the view is down Craig Road from its terminus. (This is photo #2 in the balloon test report.) There are several utility poles marked by us on Figure 2 (#1-4). Between pole 3 and 4 there is a solitary pine tree to the left of the power lines. Figure 1 shows this tree on the grass area in front of the moving and storage company building (within circle). The position of the tree can be confirmed by viewing drawing C-1A of the 26 January 2010 site plan drawings.

While the tree itself is not shown on the site plan drawing, its location can be confirmed because the utility poles are indicated. Our utility pole #1 (foreground of Figure) is not shown on drawing C-1A. The drawing's utility poles straddling the frontage of the moving and storage building are the third and fourth utility poles on Figure . Figure shows these two utility poles also straddle the position of the tree on the building's front yard. Figure 1 confirms this analysis because the only tree in the line of sight is this one on the front grass area. (Closer inspection of the same image on Google Earth confirms the other dark marks on the sightline are not trees.)

Now that we have established the tree's position, consider the upper (orange) line drawn by us on Figure 2. This is the sight line from the balloon test report's photo #2 position to the tower position. It follows a path to the left of the pine tree. Figure , however, indicates the blimp is above the tree from this perspective. A second (orange) line is drawn from the photo location across the tree to the general location of the proposed site. At best, there appears to be at least a 40-50 foot offset of the balloon from directly over the tower position employed in the balloon test.

The offset in the blimp position is greater than the first estimate of 40-50 feet for the following reason. Since the view of the blimp is not at right angles to the blimp, it is also not at right angles to the wind direction. The apparent offset to the location 2 point

[1] This image is taken from a scanned copy of the TEP balloon test report. We do not have an electronic copy of the report. Some resolution may have been lost in the scan; however it still illustrates how small the balloon is at less than 1000 feet, and how the angle of the photo to the orientation of the balloon may affect the apparent width.

of view is foreshortened as shown in Figure . Based on the balloon test report, which says the wind was out of the northwest, and on the apparent angle of the blimp to photo #2, let us assume an estimated 60 degree divergence between the photo point of view and the wind direction (Angle a.). Thus there is a foreshortening based on a 30 degree difference between the apparent and the actual offset (Angle .b). This 30 degree cosine error changes the 40-50 foot apparent offset to a 46 to 58 foot actual offset.

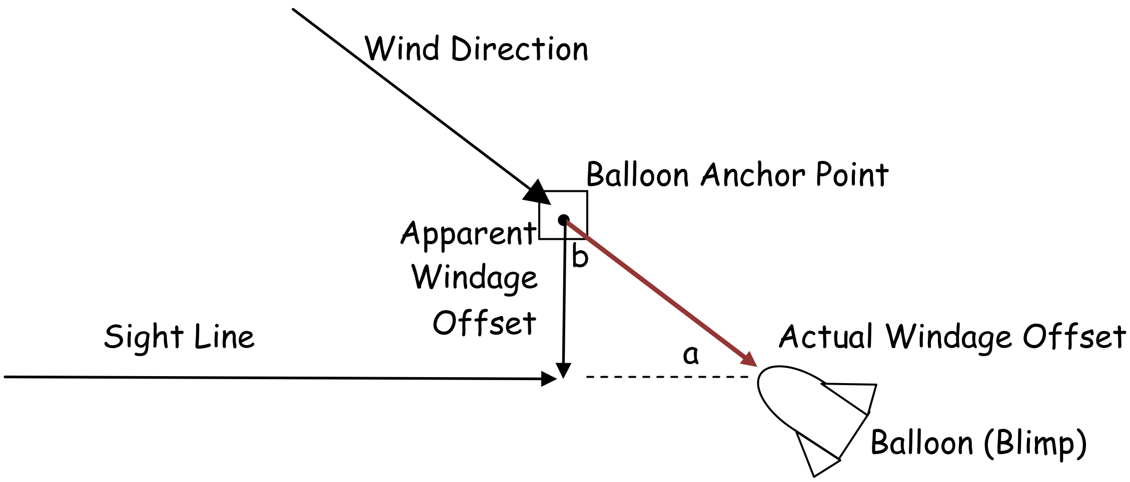

Figure 3 - Difference between Apparent Windage and Actual Windage – Plan View (angles chosen to illustrate the point; not to scale)

Having demonstrated the potential offset of the blimp due to windage, we now see what the impact of that offset is on the height of the blimp. Assume the tether has no catenary curve to it. (Because of this sag in the line, the line is always longer than distance between the ends of the line, but we will assume the difference is negligible.) Assume the distance from the anchor point to the top of the balloon is exactly 170 feet, as indicated in the balloon test report.

The upper side of the blimp is 170 feet away from the anchor point, up a diagonal hypotenuse and 46 to 58 feet offset laterally. Figure 1 shows this as the “Straight Line Distance.” The blimp would be between 164 and 160 feet high (“Actual Height”, Figure 1). The tilt of the tether (Angle c., Figure 1) is not at 85-90 degrees from horizontal as stated in the balloon test report, but 70-74 degrees based on this analysis.

Fortunately, our analysis indicates there may be only about a ten foot error in the blimp height *in photo #2* of the <1000 foot set of photos. Unfortunately, this error may be more or less by a significant amount for each photograph in the balloon test report. The photographer is observing the balloon [blimp] from a particular location. As the wind varies, the balloon bobs about. The photographer observes the balloon for a short time and identifies by eye the short-term highest observed elevation. Then the photographer attempts to take a photo when the balloon reaches this temporal peak elevation. This temporal peak elevation may not be the "apex" during the entire flight time of the balloon, as the wind speed, direction gusts, and brief moments of near calm vary. (The "apex" is obtained when the wind is at its most calm during the flight; most apparent peaks of the balloon movement over the short term will be less than the true "apex.")

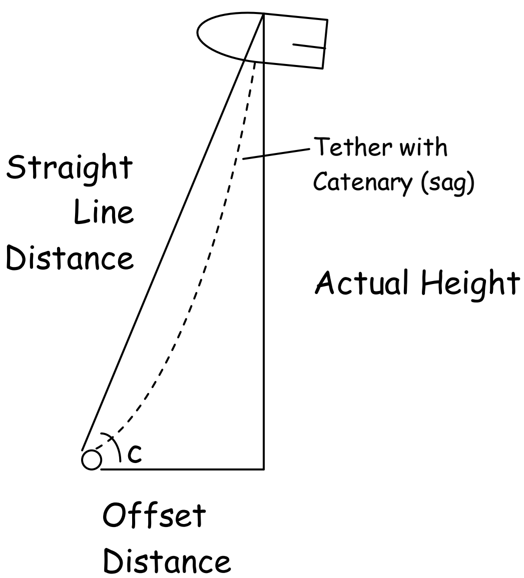

Figure 1 – Elevation View of Balloon (Blimp) and Tether

To this point in our analysis, we have focused on the offset error of the blimp due to the wind. Our goal was to show that the impact of windage on blimp height is not trivial.[2] TEP did not perform simple checks during the balloon test to provide a rigorous, peer

[2] We have not raised the question of the accuracy of the lateral position of a simulated tower that results from the offset. This is more important for close-in simulations where the appearance of the balloon - and therefore the simulated tower - may be shifted a large percentage of the width of the photograph. At longer distances, such as those taken in the balloon test report at more than 1000 feet, the positional error of a 50 foot offset is negligible.

reviewable report. In the following section, we proceed to the question of the accuracy of the photosimulations.

Pg. 3 Para. 4 **Request for Camera specifications.**

TEP provided the camera specifications as requested. The camera has an equivalent focal length range of 38 to 380 mm.[3] The wide angle setting (38 mm) was utilized in the landscape view photosimulations.

The TEP response states, “The photo simulation “D” provided in their [BSL’s] report is completely subjective and arbitrary,” and asks, “How do we or anyone else for that matter, know the dimensions of the “real” towers that were simulated in his photograph as comparisons to what is being proposed?” We believe that anyone skilled in the practice of accurately rendering photosimulations would have a basic understanding of optics and would have understood our explanation in our critique of the TEP photosimulations. There is nothing arbitrary about it.

Fundamentally, any camera set to a given equivalent focal length will take the same picture of a subject from the same position. The only differences would occur if the aspect ratio (width to height ratio) of the image were to differ between cameras. Fortunately, common consumer digital camera formats employ the same aspect ratio (4:3). Specifically, our Olympus C-3040 has the same aspect ratio as the TEP camera.

In our critique, our first question was what was the TEP equivalent focal length of the TEP photos? Lacking any information about the camera at that time, we took a photo of a tower that is the same height as the proposed tower. We positioned our camera the same distance from the real tower as the TEP photo was taken from the proposed tower site. We used a 35 mm focal length and a 50 mm focal length. We overlaid the full 4:3 images of our 35 mm and our 50 mm photographs over the full TEP image in their photosimulation report. Consequently, we had two known focal lengths shots of a real tower and an unknown focal length shot with a simulated tower. All three images were the same physical dimensions.

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[3] Equivalence to a 35 mm film camera focal length, which is the customary method for comparing the focal lengths of digital cameras.

The graphic software enabled us to carve a "hole" in the TEP image to reveal the towers in our 35 mm and 50 mm images. We concluded that the TEP photosimulation appeared to roughly agree on height with our 35 mm actual photograph.

We agree that to the extent the blimp was captured at or near the target 170 foot height, a photosimulation relying on the blimp's height would provide a reasonable reference for a simulated tower's height.

After determining that our 35 mm equivalent focal length image of a real 170 foot tower taken at the same distance as the TEP photosimulation had essentially the same height as that of the photosimulation, we knew we were close to the TEP equivalent focal length. (Indeed, we were close – ours was 35 mm and theirs was 38 mm, a less than 10% difference.)

After establishing our estimated equivalent focal length of the TEP images, we overlaid the images as described above to show that the breadth of the tower in the simulation was understated. Our critique should have been sufficient to address TEP's "how does anyone know?" question. This explanation reinforces our earlier description.

This sequence of steps is geometrically rigorous and not the least bit arbitrary.

Pg. 3, Para. 5 **"Nevertheless, a simulated tower set to the balloon height may not be the correct width on the selected photograph."**

TEP responded to our statement saying the length and width of the balloon are known and the photo rendering technician "scales the height and width of the [simulated] structure accordingly." The length of the blimp is 2.5 times the width and the orientation of the balloon from a 1700 foot distance is not readily discernable from the photographs, resulting in a 2.5:1 horizontal dimensional uncertainty. In addition, at 1700 feet distance, the size of the balloon on the image occupies very few pixels, potentially resulting in quantization error where the width of a blimp whose cross-section to the viewer is somewhere in the range of 5.2 to 13+ feet.[4]

[4] A potential further complication: if the working image utilized a "lossy" image compression format, such as JPEG compression, the fine detail, if any, of a small floating object against a light blue sky can be lost in the compression.

TEP further offers the defense that TEP chose the methodology for executing the photography and photosimulations because, "There were no focal length requirements stated in section 3.7.10 of 3.7.11 of the Wireless Communications Facility Special Permit Rules & Regulations that were provided to TEP as the Scope of Services for the undertaking." Those skilled in the field of generating photosimulations are aware of the well-known norms of such work. In a recent example, we cite here the comments of Mr. George Janes, AICP, Executive Director of Environmental Simulation Center, LTD in a letter to a land use board in Shawangunk, NY, January 22, 2008:

> ***Lenses***
> *Most photographs used for photosimulation should be taken using a normal, or 50mm lens. This lens has been shown to create an image where distance relationships are similar to the perception of the human eye. Simply, lenses less than 50mm will make elements in the photograph appear smaller that they would to the human eye, while larger lenses will make elements of the photograph appear larger. [Footnote:* Research has shown that there is variation between people so that any lens between 50 and 55mm is an acceptable lens to represent distance relationships of the human eye.] *If more than two viewpoints are selected for analysis, I recommend that one or two photosimulations should be done using a zoom lens to simulate the acuity of the human eye when it focuses on an object in the distance. This zoom lens should be 85mm or larger. Panoramic lenses (or the use of panoramic stitching) should not be used.*

Pg. 5, **Photographs "B & C"**

Finally, TEP challenges our field photos of an actual 170-foot tower from 1700 feet,[5] suggesting that they "appear to be taken at slightly different locations based on the shadows on the right of the photo and the vegetation change on both sides of the road. This may be the result of difference in focal length but it may also be a result of the photographs being taken from slightly different locations."

The B and C images are actually from the same photograph. Image C is simply a subset of image B. There is no difference in the content of C compared to the same content in B. The original photo was taken at 35 mm equivalent focal length. Mathematically, the 50 mm focal length simply captures a narrower angle of the same view. We calculated the difference in the angle of view and cropped the 35 mm photo to provide the

[5] We measured the distance from the camera to the tower with a laser rangefinder.

information that would be in a 50 mm photo. We then expanded the 50 mm crop to obtain a same-size image as the 35 mm image, both of which were overlaid on the TEP photosimulation. This 50 mm crop process is identical to the feature on digital cameras called "digital zoom".

Conclusion

Height

Based on the new information provided by TEP regarding the production of its tower photosimulations, TEP relied on estimations of balloon height and tower width rather than field measurements and graphical computations. This leaves the results with a degree of uncertainty that could have been avoided. In our opinion, the balloon height, and therefore the simulated tower height is likely to be low by ten feet or more. This is not a significant error for the long distance simulations in the present case, but the error is in favor of diminishing the simulated size of the tower.

Breadth

We reiterate that the breadth of the tower in the simulation appears to be understated based on our field photograph of a real tower taken from the same distance and a *lesser* focal length. Proportionally, the error in breadth is a more significant error than the height uncertainty.

Realism

Finally, the "normal" equivalent focal length of 50-55 mm was not utilized. The wide angle equivalent focal length of 38 mm presents a wider field of view in the image, which exaggerates the apparent distance of the subject tower as presented in the photosimulation. This exaggerated distance makes the tower appear smaller in the photosimulation than it would be perceived by individuals seeing it in the field.

Overall, the photosimulations prepared by TEP may be somewhat helpful in evaluating visual impact, as long as one understands the methodology significantly favors understating the visual experience of the proposed tower.

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